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Effects of Kerosene on the

Germination and Growth of Indian Corn

Botany

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EFFECTS OF KEROSENE ON THE
GERMINATION AND GROWTH
OF INDIAN CORN

BY

JOHN HAMILTON WHITTEN

A. B. UNIVERSITY OF ILLINOIS, 1911

THESIS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE

DEGREE OF
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IN

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

John Hamilton Whitten

ENTITLED Effects of Kerosene on the Germination and Growth
of Indian Corn

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF

Master of Arts

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In Charge of Major Work

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Recommendation concurred in:

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Effects of Kerosene on the Germination and Growth of Indian Corn.

In December 1908 Dr. Stephen A. Forbes published a bulletin from the Illinois Agricultural Experiment Station at Urbana giving the results of a series of experiments which had to do with the effects of kerosene on the germination and growth of Indian corn. In describing his results Dr. Forbes states that "perplexing discrepancies" (Bull. 130 p. 10) were of rather frequent occurrence and admits that the scope of his investigations was too limited to warrant general conclusions.

Previous to the time of the publication of the bulletin mentioned above there had been some work done on the same subject under the direction of Professor Charles F. Hottes in the physiological laboratory of the University of Illinois. The work which was being supervised by Professor Hottes was never completed; but from the work done and from the published statements of Dr. Forbes, Professor Hottes was lead to believe that the physiological aspects of the subject were of sufficient interest to warrant a more thorough investigation; and it was on his suggestion and under his direction that the work herein described was undertaken.

Preliminary Experiments.

In order to decide on a method of procedure a series of preliminary tests was made during the summer of 1911. In these tests an attempt was made to learn something regarding the nature of the conditions affecting the germination and growth of Indian corn immersed in kerosene for varying intervals of time, and thus to discover the causes underlying the wide variation in the per cent of germination and growth of corn similarly treated, or the "perplexing discrepancies"

referred to by Dr. Forbes. The preliminary investigations were conducted along the following lines:

1. Methods of Eliminating the Kerosene.

An effort was made to reabsorb the oil from the grain as fully as possible and thereby eliminate any ill effects which its presence might have during germination. Powdered yellow clay, plaster of Paris and dry filter paper were used for this purpose. The corn was also placed on dry filter paper and exposed to the air after removing it from the kerosene in order to allow the oil to volatilize. For short periods, two days or less, an application of plaster of Paris was the most effective. For periods of five days or longer exposure to the atmosphere was equally good, and as the latter method had the advantage of being somewhat simpler it was used in the final tests almost exclusively.

2. Soaking in Water.

Grains immersed in kerosene for varying lengths of time were soaked in water for from one to twenty-four hours and then placed under appropriate conditions for germination. The results showed that soaking in running water for periods of from four to six hours was not injurious and in some instances seemed to be slightly beneficial. When soaked for longer periods injury, manifested by a reduction in the per cent of germination, became apparent. Irregularities in later growth seemed to appear more frequently among the kernels soaked even for the shorter periods than among the unsoaked kernels. This fact caused me to eliminate the soaking in water altogether from the larger part of the later tests;

3. Methods of Germination and Culture.

The grains were germinated in the ordinary pans for that purpose,

in yellow clay, sand, sawdust, black loam, various mixtures of sand and sawdust, and of sand and black loam. Of these the sawdust was the only one which showed any harmful effects. The germinating pan was excluded for the reason that it was necessary to observe the growth for some time after germination. A mixture of black loam and sand yielded as high a per cent of germination as any of the others. It was selected for the final tests largely because it conformed more nearly to the natural conditions of growth.

4. Moisture Content of the Soil.

The moisture content of the soil was varied from the minimum amount necessary to produce germination to the point of complete saturation. Here the results were so diverse for the different degrees of saturation that it was considered necessary to make three sets of tests identical in every way except the moisture content of the soil. The first representing approximately the minimum amount required for germination; the second, the maximum amount in which normal grains would germinate and grow; and the third, an amount which would be an approximate average of these extremes.

No effort was made at completeness in any of these preliminary tests. The various methods were eliminated just as soon as it was learned that they were of no special value in the solution of the problem. The data acquired from these tests is used only in so far as it has a direct bearing on the final methods selected for carrying on the experiments.

Preparation of Soil.

A quantity of potting soil, a very rich black loam, was obtained from the University green house. It had been prepared by piling up sodded turf and allowing the vegetable matter to decompose. After

drying to a sufficient degree to render suitable for handling, the soil was screened through a sieve of one-twelfth inch mesh and mixed with sand, similarly screened, in the proportion of two parts of loam to one part of sand. After mixing these two constituents into a perfectly homogeneous mass, the following method was employed for determining its capacity to hold water:

1. Weighed one liter of soil in its normal condition.
2. Dried the soil in an oven at 100 degrees C. until it ceased to lose weight at that temperature and recorded the weight of the dry soil.
3. Placed the dry soil over filter paper in a funnel and added small quantities of water at frequent intervals until the soil no longer gained in weight after the surplus water had drained off through the funnel.

The object in weighing the soil in its normal condition at the beginning of the test was to obtain equal volumes of soil for each test. This can not be obtained by measuring the volumes with the ordinary dry measures, because the amount of solid matter in a given volume of soil varies with the amount of water it contains. For example, a liter of soil which was 22 % saturated weighed 1000 grams, while a liter of the same soil 30 % saturated weighed 887 grams. This change in weight, 113 grams, of equal volumes being produced by the addition of approximately 25 cc. of water. The reason for this is evident: the addition of water to the soil up to a certain limit causes it to be light and flocculent, so that a given quantity of solid matter occupies more space. From this and other similar experiences it was learned that a given quantity of soil must have a standard weight if equal volumes are to be obtained. It was convenient to adjust the moisture content of the soil used in these experiments so

that at the beginning of each test a liter would weigh approximately 1000 grams.

The difference between the weight of the soil in its normal condition and the weight of the dry soil gives the weight of water in the normal soil, and the difference between the weights of the dry and the saturated soil gives the weight of water necessary to saturate the soil. Knowing these facts it becomes a simple matter to add water to the normal soil in quantities to make it any per cent of saturation.

The following table shows the records of a few typical tests made to determine the capacity of the soil for holding water:

Wt. of Norm. soil	Wt. of dry soil	Wt. of H ₂ O in norm. soil	Wt. of Saturated soil	Wt. of H ₂ O in saturated soil	% of saturation of norm. soil
1020	934	77	1302	359	21
1000	928	72	1253	325	22
1000	924	76	1262	338	22
938	851	87	1201	350	24.8

Tests such as are indicated above were made frequently during my experiments but the variations were so slight that it is unnecessary to record more than is here given.

The corn was grown in pans 35 cm. by 20 cm. and 7 cm. deep, provided with closely fitting covers in which there were openings for aeration.

When but 30 % saturated it was possible to mix the soil thoroughly after the water had been added without puddling. The soil, however, could not be so mixed when containing the higher proportions of water. In these cases a thin layer of soil was placed in the pans and then the proportionate amount of water sprayed evenly over the surface,

another layer of soil added and sprayed again, repeating the process until the desired amount of soil was in the pan and the proper amount of water added to give the required moisture content. In this way mixing was avoided and yet the water was evenly distributed through the soil.

Planting.

For the 60 and 90 % saturation tests four liters of soil were used in the respective pans while for the 30 % test five liters were used; one liter of which in all cases was reserved for covering the grains after they had been placed in the soil. The grains were planted in rows one inch apart and one-half inch from each other in the rows. To aid in placing the kernels a wire netting with one-half inch mesh was placed on the surface of the soil and the kernels inserted through the netting into the soil. In this way observations might be made and records kept of any individual kernel in the pan. The kernels were thrust into the soil in an upright position until the butts were flush with the surface and then the final liter of soil spread evenly over them.

The gross weight of the pan and contents was taken after the planting and labelling were completed. This weight was kept constant by the addition of water with an atomizer, morning and evening, to make up the loss by evaporation until the growing shoots were well through the soil. The pans were kept covered during germination and this period of initial growth. The critical period of the test then being passed, the covers were removed to admit light; and no farther effort was made to keep the moisture content constant. Water was simply added in sufficient quantities to keep the corn in good growing condition.

No claim is made that the above method for obtaining and maintaining the water content of the soil was absolutely accurate. It is

certainly true, however, that the degree of saturation did not vary more than 2 or 3 %, and that was sufficiently accurate for my purpose.

Temperature.

All of my tests were made at room temperature, and as the work was begun in June and continued until the following May the variations were considerable. The extremes noted were 15 and 35 degrees C. These extremes occurred but rarely. The normal variations were between 18 and 25 degrees C. As a rule, whenever the temperature conditions of the room showed any ill effects on the tests they were repeated. Trial 3 in Tables II and III are exceptions to this rule. The temperature during those tests was at the lower limit nearly every night.

Explanation of Tables.

The time indicated in the column under the heading of kerosene treatment gives the period during which the kernels were immersed directly in the kerosene. "After treatment" means how the corn was treated after it was removed from the kerosene and before it was planted. In every case except where it is specifically stated that there was no after treatment, the corn was superficially dried with a towel or blotting paper immediately after removing it from the oil. This fact is not indicated in the tables. In those cases in which the after treatment is indicated by the word none, the kernels were planted while dripping wet with kerosene.

A kernel was counted as germinated if it showed a decided growth of root or shoot beyond the ovary wall.

In the column under the heading of retarded growth, were recorded the seedlings the growth of which was below the limits of individual variation. These plants, however, showed no evidence of weakness ex-

cept that they were smaller than the others. There was nothing to indicate that they would not, in time, have overcome the retardation and matured normally; but since that fact could not be known positively, these seedlings were deducted before calculating the per cent of normal growth. Under the heading of injured growth there were recorded the seedlings the condition of which was such that, while there was a decided germination, they certainly could not grow to maturity. The plants which are described as weak were very different from the retarded plants. The former usually showed evidence of decay at the base of the shoot.

The per cent of germination is computed from the number germinated as compared with the number tested. The per cent of normal growth is determined by deducting the retarded growth and the injured growth from the number germinated and comparing the remainder with the number tested.

The variety of corn used in Tables I, II, and III was Boone County White, a white dent corn. In Table IV the Champion White Pearl and the Golden Eagle varieties were tested. The former has a hard, smooth, white kernel; the latter is a yellow dent variety. That used in Table V was a yellow dent corn but the particular variety was not known.

The kerosene used was a product of the Standard Oil Company which is on the market under the trade name of "Perfection".

In all the tests which are recorded in the Tables, the kernels were carefully selected before immersion in kerosene but no selection was made after removing them from the oil.

The corn was allowed to grow until it was about six inches tall. It was then taken up and the roots and kernels carefully examined.

Abbreviations used in Tables.

s.dead,	means shoot dead.	col.th.	means coleoptile thickened.
r.dead,	" root dead.	P.P	" plaster of Paris.
curled,	" leaves curled.		

Table I.

Soil 30 % Saturated.

Tr	No. of kernel	Kerosene treatm't	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growth
1	50	dipped	24 hr. air	50	0	0	- -	100	100
	50	1 min.	"	50	0	1	s. dead	100	98
	50	5 min.	"	50	1	1	"	100	96
	25	check		25	2	1	"	100	88
2	50	dipped	24 hr. air	50	0	0	- -	100	100
	50	1 min.	"	50	0	1	s. dead	100	98
	50	5 min.	"	50	0	0	- -	100	100
	50	check		50	2	0	- -	100	96
3	50	10 min.	48 hr. air	50	1	0	- -	100	98
	50	15 min.	"	50	1	0	- -	100	98
	50	30 min.	"	50	0	3	s. dead	100	94
	25	check		25	0	1	"	100	96
4	50	1 hr.	36 hr. air	50	0	1	weak	100	98
	50	2 hr.	"	50	0	0	- -	100	100
	50	3 hr.	"	50	0	1	s. dead	100	98
	50	6 hr.	"	50	0	0	- -	100	100
	50	8 hr.	"	50	0	2	1 weak 1 curled	100	96
	50	14 hr.	"	50	0	0	- -	100	100
	50	check		50	1	0	- -	100	98
5	50	1 da.	4 da. air	50	0	0	- -	100	100
	50	3 da.	"	50	2	2	s. dead	100	92
	25	6 da.	"	25	0	0	- -	100	100
	25	check		25	0	0	- -	100	100
6	25	1 da.	4 da. air 3 hr. H ₂ O	25	0	0	- -	100	100
	25	3 da.	"	25	0	0	- -	100	100
	25	6 da.	"	25	0	0	- -	100	100
	25	check		25	0	1	r. dead	100	96
7	100	1 da.	30 da. air	100	0	2	curled	100	98
	100	3 da.	"	100	1	1	weak	100	98
	100	6 da.	"	100	1	2	"	100	97
	25	check		25	0	0	- -	100	100
8	100	10 da.	5 da. air	95	2	5	2 curled 3 weak	95	88
	100	20 da.	10 da. air	90	0	8	s. dead or weak	90	82
	100	30 da.	"	86	0	10	"	86	76
The Following are Summaries Taken from Table IV.									
	200	4 da.	cf. Table IV	199	0	6	cf. Table IV	99½	96½
	1000	11 da.	"	977	16	31	"	97.7	93
	600	25 da.	"	568	2	41	"	93	87½
	600	50 da.	"	518	6	38	"	86.3	79
	150	check		147	1	1	"	98	96.6

Table II.

Soil 60 % Saturated.

Tr	No. of kernel	Kerosene treatm't	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growth
1	50	dipped	24 hr. air	50	0	0	- -	100	100
	50	1 min.	"	49	1	1	s. dead	98	94
	50	5 min.	"	50	0	0	- -	100	100
	25	check		25	0	0	- -	100	100
2	50	dipped	24 hr. air	46	0	0	- -	92	92
	50	1 min.	"	47	0	1	s. dead	94	92
	50	5 min.	"	46	0	0	- -	92	92
	50	check	"	50	0	0	- -	100	100
3	50	10 min.	48 hr. air	25	0	5	s. dead	50	40
	50	15 min.	"	35	0	7	"	70	56
	50	30 min.	"	11	0	2	"	22	18
	25	check		25	0	1	"	92	88
4	50	1 hr.	36 hr. air	42	0	1	s. dead	84	82
	50	2 hr.	"	46	2	3	"	92	82
	50	3 hr.	"	45	2	2	"	90	82
	50	6 hr.	"	46	1	2	1 s. dead 1 curled	92	86
	50	8 hr.	"	45	2	2	1 s. dead 1 weak	90	82
	50	14 hr.	"	47	2	2	1 s. dead 1 curled	94	86
	50	check		50	0	1	curled	100	98

Table III.

Soil 90 % Saturated.

Tr	No. of kernel	Kerosene treatm't	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growtn
1	50	dipped	24 hr. air	27	0	0	- -	54	54
	50	1 min.	"	22	0	0	- -	44	44
	50	5 min.	"	20	1	0	- -	40	38
	25	check		22	0	0	- -	88	88
2	50	dipped	24 hr. air	43	2	1	s. dead	86	80
	50	1 min.	"	38	0	3	"	76	70
	50	5 min.	"	35	1	2	"	70	64
	50	check		44	1	2	"	88	82
3	50	10 min.	24 hr. air	14	0	1	s. dead	28	26
	50	15 min.	"	11	0	2	"	22	18
	50	30 min.	"	4	0	0	- -	8	8
	25	check		15	0	0	- -	60	60
4	50	1 hr.	36 hr. air	28	0	1	col. th.	56	54
	50	2 hr.	"	24	1	0	- -	48	46
	50	3 hr.	"	22	1	1	weak	44	40
	50	6 hr.	"	26	0	1	s. dead	52	50
	50	8 hr.	"	21	2	1	curled	42	36
	50	14 hr.	"	25	0	1	weak	50	48
	50	check		50	0	1	curled	100	98

Comparison Between The Champion White Pearl
And The Golden Eagle Varieties.

Table IV.

Soil 30 % Saturated.

Tr	No. of kernel	Kerosene treatm't	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growth
1	50 Y	4 da.	Towel dry	50	0	0	- -	100	100
	50 W	"	"	50	0	0	- -	100	100
	50 Y	"	Towel dry, 3 hr. H ₂ O	49	0	6	curled	98	86
	50 W	"	"	50	0	0	- -	100	100
	25 W	check		25	0	0	- -	100	100
2	50 Y	11 da.	Towel dry	49	0	6	5 curled 1 s. dead	98	86
	50 W	"	"	49	0	1	weak	98	96
	50 Y	"	5 hr. H ₂ O	46	0	5	3 curled 2 weak	92	82
	50 W	"	"	49	2	0	- -	98	94
	50 Y	"	4 da. air	50	0	2	curled	100	96
	50 W	"	"	50	0	0	- -	100	100
	50 Y	"	4 da. P.P.	50	0	1	weak	100	98
	50 W	"	"	48	4	2	1 s. dead 1 weak	96	84
	50 Y	"	4 da. air 5 hr. H ₂ O	49	0	5	weak	98	88
	50 W	"	"	50	0	1	curled	100	98
	50 Y	"	4 da. P.P. 4 hr. H ₂ O	50	1	0	- -	100	98
	50 W	"	"	50	1	1	curled	100	96
	50 Y	"	15 da. air 5 hr. H ₂ O	47	0	5	weak	94	84
	50 W	"	" 2	48	5	0	- -	96	86
	50 Y	"	15 da. air	49	0	0	- -	98	98
	50 W	"	"	48	0	0	- -	96	96
	50 Y	"	15 da. P.P. 5 hr. H ₂ O	47	1	1	curled	94	90
	50 W	"	"	49	1	1	weak	98	94
	50 Y	"	15 da. P.P.	50	0	0	- -	100	100
	50 W	"	"	49	1	0	- -	98	96
	50 W	check		48	1	0	- -	96	94
	50 Y	25 da.	none	47	0	10	4 s. dead 5 curled 1 col. th.	94	74
	50 W	"	"	48	0	2	s. dead	96	92
	50 Y	"	Towel dry	48	0	3	2 weak 1 curled	96	90
	50 W	"	"	48	1	2	s. dead	96	90
	50 Y	"	7 da. air	47	0	6	4 s. dead 1 r. dead 1 col. th.	94	82
	50 W	"	"	46	0	2	s. dead	92	88
	50 Y	"	7 da. P.P.	45	0	4	1 s. dead 2 col. th. 1 curled	90	82

Table IV (Continued)

Soil 30 % Saturated.

Tr	No. of kernel	Kerosene treatm't	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growth
4	50 W	25 da.	7 da.P.P.	49	0	1	s.dead	98	96
	50 Y	"	14 da.air	49	1	5	1 weak 4 s.dead	98	86
	50 W	"	"	47	0	4	3.s.dead 1 r.dead	94	86
	50 Y	"	14 da.P.P	48	0	2	1 s.dead 1 r.dead	96	92
	50 W	"	"	46	0	0	- -	92	92
	50 Y	50 da.	none	33	0	7	1 s.dead 4 curled 2 weak	80	66
	50 W	"	"	46	1	2	1 s.dead 1 r.dead	92	86
	50 Y	"	Towel dry	39	0	5	3 curled 2 s.dead	78	68
	50 W	"	"	45	0	4	s.dead	90	82
	25 Y	check		24	0	0	- -	96	96
	50 Y	50 da.	7 da.air	38	0	3	s.dead	76	70
	50 W	"	"	49	0	2	1 s.dead 1 weak	98	94
	50 Y	"	7 da.P.P	42	0	5	3 s.dead 2 weak	84	74
	50 W	"	"	49	0	2	1 s.dead 1 weak	98	94
	25 Y	check		25	0	1	col.th.	100	96
	50 Y	50 da.	14 da.air	40	3	1	s.dead	80	72
	50 W	"	"	48	2	1	s.dead	96	90
	50 Y	"	14 da.P.P	40	0	7	5 s.dead 1 curled 1 weak	80	76
	50 W	"	"	44	0	0	- -	88	88
	1200 Y	(total for table IV)		1109	5	90		92.4	84.5
	75 Y	check		74	0	1		98.7	97.3
	1200 W	(total for table IV)		1143	18	27		95.2	91.5
	75 W	check		73	1	0		97.3	96.

Types of Abnormalities.

With the tests in 60 and 90 % saturated soil abnormally swollen kernels were of very frequent occurrence. A thin watery liquid collected inside of the ovary wall so that several drops might be extracted from a single kernel. Microscopical examination showed the presence of both perfect and corroded starch grains in this liquid. On two different occasions several of these kernels in the 90 % saturated soil seemed to undergo fermentation. The ovary walls were ruptured and the liquid made its way to the surface of the soil where it spread out and, drying, formed a hard, white crust. Under the microscope this crust showed corroded starch grains and a large number of bacteria. The bacteria were of uniform shape and size and apparently belonged to a single specie. In each case when fermentation occurred the temperature of the room was considerably higher than the ordinary, indicating that the condition was intimately associated with the increased heat and the high degree of saturation of the soil. Swollen grains occurred among the kernels which had failed to germinate and among those which were growing normally. They were also found among the check kernels as well among those which had been immersed in kerosene. Their occurrence, however, was much more frequent with the latter. From the observations made there was nothing to indicate that the swollen condition of the kernels had any bearing on the germination or growth of the corn, and consequently it is described here merely as an interesting coincident. No swollen kernels were found in the soil 30 % saturated.

One of the most noticeable injuries, though by no means the most frequent, was a curled or twisted condition of the leaves, due to their inability to unfold normally in the process of growth. In a majority of cases an examination of the tips of these leaves showed that they

were dead and that they clung together because of that fact. This injury must have occurred while the leaves were still wrapped closely together within the coleoptile. It was possible to produce typical cases of the injury on the check seedlings by touching the tip of the growing shoot with an injurious reagent immediately after it appeared through the coleoptile. Of the reagents used for this purpose sulphuric acid was the most certain to cause the abnormal growth. Kerosene when so applied produced the injury in a few cases, but since it was not so deadly to the plant tissue it was not so effective in producing the injury at that particular stage of growth as the more active sulphuric acid. The injury appeared occasionally on the check seedlings, but there can be no doubt that the unusual frequency of the deformed condition was due to the effects of the kerosene acting as indicated above.

Another abnormal growth attributable to the kerosene was a much enlarged and thickened coleoptile which the shoot did not rupture. An abnormal development of the coleoptile appeared frequently, but in most cases it was finally ruptured and the structures within grew out, usually in a more or less weakened condition. In the tabulation of the results the coleoptile is recorded as being thickened only when the structures failed to appear through it. Whenever this unusual development appeared it was observed that the tip of the growing shoot within was much farther below the tip of the coleoptile than it was in the normal seedling. There occasionally appeared one of these abnormal structures in which there was no evidence of a growth of the plumule. The coleoptile being entirely empty. These facts seemed to indicate that the enclosed structures were more sensitive to the action of the kerosene than the coleoptile itself, and that the enlargement was probably due to the failure of the

plumule to develop as well as to the direct stimulus of the kerosene on the coleoptile.

The most frequent injury was the complete death of the shoot. This happened over and over again while the root grew perfectly normal. Only very rarely during my experiments did the shoot grow from a kernel in which the root had been killed.

The injuries mentioned above were not as distinct from each other as the descriptions might seem to indicate. As a matter of fact there was an almost imperceptable gradation from one to another. If, for example, the deformed leaves be taken as the first perceptable ill effects of the kerosene, there could be traced from that, step by step, a decreasing vitality shown by a corresponding abnormal growth, until death occurred. This fact clearly indicates that in the cases where injuries have occurred, the kerosene acts very slowly so that considerable time elapses between the first injury and death.

Explanation of Table V.

Reference has already been made to the work started on this problem in the physiological laboratory of the University of Illinois previous to the publication of Dr. Forbes' bulletin. The student to whom the work was assigned was compelled to abandon it before any definite results had been reached. Through the foresight of Professor Hottes, the corn immersed in kerosene at that time was set aside and kept in the store room of the laboratory until the present work was begun. It was in a loosely covered glass fruit jar which bore the label of February 6, 1906. Professor Hottes was able to verify the date so that there is absolutely no doubt but what the corn had been immersed in kerosene continuously since that date. The oil had become yellow and was about the consistency of thin syrup. There was

Tests With Corn Which was Put to Soak in Kerosene Feb.6,1906.

The first test was made July 11,1911. The others followed as the time of kerosene treatment indicates.

Table V.

No. of Kernel	Kerosene treatment	After treatment	No. germ	Retard growth	Injr. growth	Nature of injury	% of germ	% Norm growth
50	5yr.5mo.5da.	60hr.air	1	not	observed		2	2
50	"	washed & 60 hr.air	5	"	"		10	10
50	"	48hr.clay 12 hr.air	20	"	"		40	40
50	"	48hr.P.P. 12hr.air	22	"	"		44	44
100	5yr.5mo.22da.	7da.P.P 1da.air 8hr.H ₂ O	64	6	3	weak	64	55
35	"	60da.P.P.	25	0	0	- -	66	66
35	"	60da.air	9	0	0	- -	26	26
35	"	none	11	0	0	- -	32	32
50	5yr.10 mo. 25da.	10 da.air 3 hr.H ₂ O	10	1	0	- -	20	20
50	"	"	13	0	0	- -	26	26
<u>The following tests were made in soil 90 % saturated.</u>								
25	5yr.6mo.8da.	60da.P.P	0	0	0		00	00
25	"	60da.air	0	0	0		00	00
<u>The following tests were made in soil 60 % saturated.</u>								
25	5yr.6mo.8da.	60da.P.P.	0	0	0		00	00
25	"	60 da.air	0	0	0		00	00
<u>The following tests were made in soil 30 % saturated.</u>								
25	5yr.6mo.8da.	60da.P.P	17	0	3	s.dead	68	56
25	"	60 da.air	11	1	1	"	44	36
20	6 yr. 2 mo.	10 da air	10	0	2	weak	50	40

about a pint of this corn, an amount far too ^mall to make any elaborate tests but sufficient to demonstrate conclusively that, under optimum conditions, a considerable portion of it was capable of germination and perfectly normal growth.

The first ten tests recorded in Table V were performed at the time when the preliminary experiments, already referred to, were being made. Of these tests the one in which one hundred kernels were used was the most satisfactory. After the treatment indicated in the table, the kernels used in this test were placed in germinating pans with barely enough moisture present to initiate the growth processes. As soon as a definite growth of root and shoot appeared the kernels were transferred to soil in which the moisture was somewhat higher, but which did not exceed 30 % of saturation. The 55 seedlings which are indicated in the column of normal growth were just as vigorous and had just as good color as the checks beside them.

Variable Permeability.

No fact in my experiments was more evident than the one which showed that the kerosene did not act uniformly on the kernels of corn which were subjected to the treatment. Some were injured, some killed, while others showed absolutely no injurious effects whatever. These conditions prevailed no matter whether the treatment was long or short. No length of treatment was found which killed or even injured all the kernels. This fact becomes significant when it is noted that the kerosene treatment was varied from a mere dipping to continuous immersion for a period of six years and two months.

Rather early in my work it was suspected that the oil penetrated some kernels more readily than others. The embryos of some grains had an oil soaked appearance after the kerosene treatment while others

seemed to be free from the oil. To get farther evidence on the permeability of the grains to the oil, some kerosene was colored with Sudan III; and 200 kernels of the Champion White Pearl corn were placed in it. After thirty days immersion the corn was removed from the colored kerosene and dried superficially with a towel. One hundred of them were cut transversely through the middle of the embryos. Of these, 73 kernels showed absolutely no trace of the colored oil in the embryos; 7 were very slightly stained with the red color; while the remaining 20 were deeply stained. In no case was there any evidence of kerosene in the endosperm. The remaining one hundred kernels which had been treated identically, were left exposed to the air over night and then planted in a 30 % saturated soil. Of the seedlings which developed from these kernels 71 were normal in every respect; 4 were retarded in their growth; and 10 were decidedly injured. The close correspondence between the number of kernels which were free from the stain in the one hundred cut open and the number of normal seedlings developing from the one hundred planted is evident. Furthermore, in the second part of the test all the kernels which seemed to have been penetrated by the kerosene were planted in a row by themselves. There were twenty-five of them and only two normal seedlings developed from that row.

It was thought before the above test was made that it might be possible for the kerosene to enter the grain and the coloring matter to be excluded, and for this reason the value of the test was doubted, but the action of the stain was so decidedly different on the different kernels that it showed conclusively that some kernels were more permeable to the colored kerosene than others.

It has already been stated that in the tests recorded in the tables, the corn was carefully selected before it was immersed in the

oil. All kernels which showed any defects were rejected, but no selection was made after the corn was removed from the oil. The following test shows the result of selection after the corn had been removed from the kerosene:

On April 20th a quantity of the Champion White Pearl Corn was removed from the kerosene in which it had been placed on February 6th, making the period of immersion 74 days. From this corn there were selected 50 kernels which seemed from external appearances to be free from kerosene. These kernels were exposed to the air for ten days and then planted in soil which was 30 % saturated. Forty-nine, or 98 per cent, of them developed normal seedlings. It is not always possible to tell from an external examination, however, even when the stain is used whether or not the kerosene enters the embryo. The structures at the tip of the kernel always take up some of the stain which spreads for some distance and frequently gives the appearance of stain within the embryo when none is present. It is also impossible to tell, without the stain, by a visual examination of the internal structures whether or not kerosene is present. Taste is a much more accurate sense than sight for determining the presence of the oil, and it was used repeatedly in deciding the permeability of the internal parts of the grain.

Conclusions.

1. Under the optimum conditions for germination and growth, Indian corn may be immersed in kerosene for a period of six days without injury. These conditions, as indicated in Table I, include reabsorbing or volatilizing the oil from the grain and the presence of a minimum amount of moisture during germination and initial growth. It will be noted in Table I that the per cent of check grains developing

normally in the tests up to and including an immersion for six days, is slightly lower than that of the immersed grains . This fact has no significance. It is wholly attributable to the normal variation and to the smaller number of kernels tested.

2. The injuries which occur to the grains immersed in kerosene for longer periods, when the optimum conditions for germination and growth are provided, are due to the penetration of the oil into the embryo where the injury is done before growth begins.

3. The failure of some grains to germinate and the abnormal development of others when placed in soil with a moisture content higher than the optimum is attributable to the combined effects of the kerosene and the additional water.

4. The injurious effects of the kerosene are in direct porportion to the length of time of immersion and the moisture content of the soil. (Tables II and III)

5. The shoot is more susceptible to injury than the root.

6. Kerosene is more injurious to some varieties of Indian corn than to others.

7. Different kernels of the same variety differ widely in respect to permeability to kerosene. The membranes surrounding the embryos of some kernels exclude the kerosene while those of others admit it.

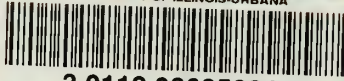
8. Some kernels may be immersed in kerosene for a period of six years and two months without injury. The membranes enclosing the embryos of these kernels are impervious to kerosene.

9. The discrepencies referred to by Dr. Forbes in the bulletin cited are, to my mind, due to the fact that the moisture content of the soil was not considered.





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